# Optimizing patch antenna arrays for MIR quantum detectors

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The development of devices based on Intersubband Transitions (ISBT) revolutionized the emission and detection in the mid-infrared region (λ=5µm-20µm). Thanks to its unique properties, ISBT allow a remarkable degree of freedom for the choice of the emission and detection wavelength, a high-speed behavior, and a high saturation threshold due to short carrier lifetime. [1]–[5] Quantum Well Infrared Photodetectors (QWIP) or Quantum Cascade Detectors (QCD) using conventional mesa show good results in the Mid-Wavelength Infrared (MWIR) region and Long-Wavelength Infrared (LWIR) region. [6], [7] However, these performances have been greatly improved using patch-antenna properties: QWIPs or QCDs embedded into a metamaterial made of subwavelength doubled-metal patch antenna resonators strongly enhance the performances up to room temperature. [8]–[10] In this work we provide a comprehensive analysis of various device parameters in order to achieve an optimized patch-antenna array according to the applications required.

The large number of geometrical parameters (periodicity, height, size…) and optical parameters (refractive index, absorption wavelength, doping concentration…) make the optimization a difficult task. We have combined numerical methods (finite element simulations) with an analytical approach such as Coupled Mode Theory (CMT) in order to quantify the interaction between the QWs and the antenna resonator as well as to extract various loss rates directly from the reflectivity curves. [11] Our approach allows us to link the losses of our systems with our constraints, i.e., handling the amount of light coupled in our system (radiative loss) and its dissipation in the contact or the QWs (non-radiative losses). This work will allow us to increase the performances of our photodetectors and unlock further experimental work such as ultra-strong coupling and laser emission using patch-antenna Quantum Cascade Lasers (QCL).

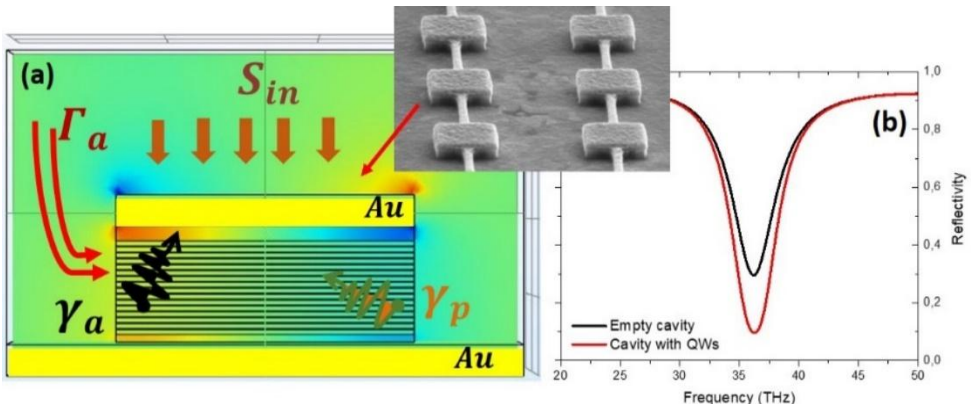


*Fig. 1: (a) Simulation of an infinite array of patch with the important parameters displayed; $\Gamma_a$ (radiative loss), $\gamma_a$ (non-radiative loss in the contact), $\gamma_b$(non-radiative loss in the ISBT) and $S_{in}$ (incoming light). (b) Reflectivity spectra of the simulations with and without absorption in the QWs. Inset: Electronical image of the device.*

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